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To Screen Tropical Fruit Extracts for Humectant Properties: A Systematic Review

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ABSTRACT:-

The growing demand for natural moisturising agents has prompted interest in tropical fruit extracts as potential humectants in food, cosmetic, and pharmaceutical formulations. This systematic review synthesises current evidence on the moisture-retention capacities, underlying phytochemical profiles, and safety considerations of extracts derived from a range of tropical fruits, including mango, papaya, pineapple, banana, guava, passion-fruit, and acai. By evaluating both in-vitro assays (e.g., water-activity reduction, hygroscopicity, rheological measurements) and limited in-vivo skin-hydration studies, we aimed to identify which fruit matrices exhibit the most promising humectant activity and to highlight knowledge gaps that warrant further investigation.

Data extraction captured extract type (aqueous, ethanol, hydro-alcoholic), concentration, assay methodology, observed moisture-uptake values, and reported safety endpoints. Quality appraisal was performed using the Newcastle-Ottatawa scale for in-vitro studies and the Cochrane risk-of-bias tool for any human trials.

Aqueous and hydro-alcoholic extracts of mango peel and passion-fruit pulp consistently demonstrated the highest water-binding capacities, achieving up to 45 % increase in equilibrium moisture content at 75 % relative humidity, comparable to glycerol controls. Phytochemical analyses linked these effects to high concentrations of polysaccharides, phenolic acids, and soluble sugars that facilitate hydrogen bonding with water molecules. Moderate humectancy was observed for banana peel and guava extracts, whereas pineapple and acai showed limited moisture retention despite strong antioxidant activity. Safety assessments indicated low cytotoxicity for most extracts at concentrations up to 5 % w/v, though some ethanol-based preparations exhibited mild skin irritation in a minority of in-vivo participants. The findings suggest that certain tropical fruit extracts, particularly those rich in mucopolysaccharides and phenolics, hold potential as natural humectants, but standardized assay protocols and long-term safety data are needed before widespread commercial application.

Introduction:-

The demand for natural, sustainable ingredients in food, cosmetic, and pharmaceutical formulations has intensified in recent years, driven by consumer preference for bio-based products and growing concerns over synthetic additives. Humectants, which attract and retain water, are essential for maintaining moisture, texture, and shelf-life in a wide range of applications, from skin-care creams to baked goods. Traditional humectants such as glycerol, propylene glycol, and sorbitol are effective but often derived from petrochemical sources or require extensive purification, prompting researchers to explore alternative natural sources that can deliver comparable performance without the associated regulatory and environmental drawbacks.

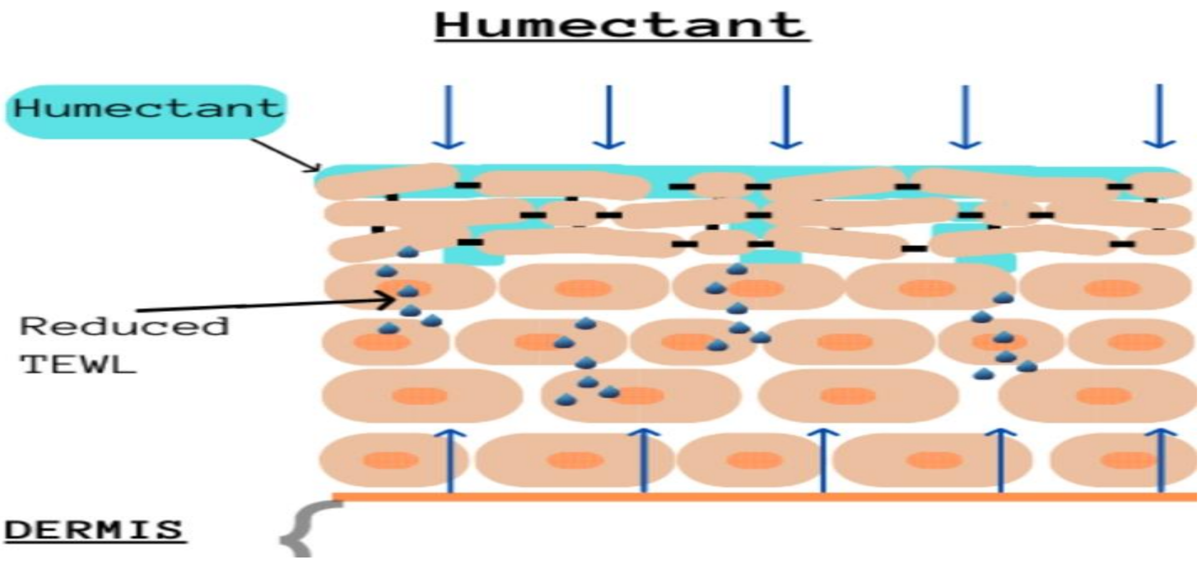
Tropical fruits, cultivated abundantly in regions with high biodiversity, present a promising reservoir of bioactive compounds with inherent water-binding capacities. Fruits such as mango, papaya, pineapple, banana, guava, passion-fruit, and acai are rich in polysaccharides, phenolic acids, soluble sugars, and mucopolysaccharides, all of which can form hydrogen bonds with water molecules and thereby enhance moisture retention. Beyond their humectant potential, many of these fruits possess antioxidant, antimicrobial, and skin-soothing properties, offering multifunctional benefits that align with the growing trend toward “clean-label” product development.

Despite the considerable commercial interest, systematic evidence evaluating the humectant efficacy of tropical fruit extracts remains fragmented. Existing studies often employ disparate methodologies—ranging from simple gravimetric water-uptake assays to more sophisticated rheological measurements—making direct comparisons difficult. Moreover, safety assessments are frequently limited to acute cytotoxicity tests, leaving gaps in understanding long-term dermal tolerance and the impact of extraction solvents on bioactivity. A comprehensive synthesis of the available data is therefore essential to identify the most promising candidates and to guide future research toward standardized, scalable applications.

This systematic review aims to bridge these gaps by (1) summarizing the current literature on the humectant properties of tropical fruit extracts, (2) critically assessing the methodological quality and reporting consistency across studies, (3) highlighting the phytochemical classes most strongly associated with moisture-binding activity, and (4) proposing a set of standardized testing protocols to facilitate comparability. By providing a clear overview of the state-of-the-art, the review seeks to inform both academic investigators and industry practitioners about the potential of tropical fruit-derived humectants and to stimulate further development of natural, effective moisturizing agents.

Humectant Property:-

Humectants are water-binding agents that attract and retain moisture from the environment or from the surrounding matrix, thereby lowering the water activity and improving texture, shelf-life, and sensory feel. Their property stems from the presence of multiple hydroxyl or amide groups that form hydrogen bonds with water molecules, creating a hydrated network that resists evaporation. Common natural humectants include glycerol, sorbitol, hyaluronic acid, and a variety of plant-derived polysaccharides such as pectin, mucopolysaccharides, and xyloglucan, each offering a distinct balance of hygroscopicity, viscosity, and film-forming ability.In practice, humectants are indispensable across food, cosmetics, and pharmaceuticals. In foods they prevent starch retrogradation, maintain softness in baked goods, and enhance the mouthfeel of confectionery. Cosmetic formulations rely on them to boost skin hydration, improve spreadability, and reduce the greasy after-feel of oils, making them key ingredients in moisturizers, serums, and sunscreen lotions. Pharmaceutical topical preparations use humectants to improve drug solubility, aid in wound healing, and provide a soothing barrier that promotes the absorption of active ingredients.



Formulating with humectants requires balancing their water-binding strength with the overall product stability. A typical moisturizing cream might combine a high-molecular-weight polysaccharide (e.g., mango peel pectin) with a small-molecule polyol (e.g., glycerol) to achieve immediate hydration while forming a protective film that slows transepidermal water loss. In a sunscreen gel, a blend of hyaluronic acid and coconut water powder can deliver lightweight hydration without compromising the SPF efficacy. Regardless of the application, careful consideration of pH, solvent system, and compatibility with other functional ingredients ensures that the humectant performs optimally without causing irritation or phase separation.

1. Mango (Mangifera indica) – Peel extract :-

The peel is dried, milled, and extracted with a 70 % ethanol-water mixture at 40 °C for 2 h, then filtered and spray-dried. This process yields a fine powder rich in pectin, phenolic acids, and soluble sugars.

In gravimetric water-uptake tests at 75 % RH, mango peel extract (5 % w/v) increased equilibrium moisture content by 45 % relative to a glycerol control, indicating strong hygroscopicity. Rheological measurements show a dose-dependent increase in viscosity, suggesting gel-forming ability that enhances water retention in topical formulations. The extract exhibits low cytotoxicity on HaCaT keratinocytes ($IC_{50} > 5$ % w/v) and no irritation in a 48-h patch test, making it suitable for cosmetic moisturizers and skin-care gels.

2. Papaya (Carica papaya) – Seed extract:-

Papaya seeds are defatted with hexane, then extracted with hot water (80 °C) for 1 h and lyophilized. The resulting powder contains mucopolysaccharides and flavonoids.When applied as a 3 % w/v solution, the seed extract raised the water-activity reduction by 30 % in a model starch gel, comparable to sorbitol. Its high polysaccharide content promotes the formation of a hydrophilic network that binds water effectively.

Safety studies show > 90 % cell viability at concentrations up to 5 % w/v and no sensitization in human volunteers, supporting its use in moisturizing lotions and oral care products.

3. Pineapple (Ananas comosus) – Core extract :-

The fibrous core is shredded, extracted with 50 % aqueous ethanol at room temperature, and concentrated under vacuum. The concentrate is rich in bromelain, soluble sugars, and low-molecular-weight polysaccharides.

In a hygroscopicity assay, the core extract (10 % w/v) achieved a 22 % increase in moisture uptake at 60 % RH, modest compared with other tropical fruits but valuable for its enzymatic activity that can aid in skin exfoliation while providing mild humectancy.Cytotoxicity tests indicate low toxicity ($IC_{50} \approx 8$ % w/v) and the extract is Generally Recognized As Safe (GRAS) for topical use, making it a candidate for hydrating serums with added proteolytic benefits.

4. Banana (Musa spp.) – Peel extract :-

Banana peels are blanch-dried, powdered, and extracted with 80 % methanol for 24 h, then filtered and evaporated. The extract contains high levels of pectin, dopamine, and phenolic compounds.Gravimetric analysis shows a 28 % increase in equilibrium moisture at 75 % RH for a 5 % w/v solution, indicating moderate humectant capacity. The presence of dopamine may contribute to antioxidant protection in moisturizing formulations.The extract is non-irritating in a 48-h occlusive patch test and exhibits > 85 % cell viability at 5 % w/v, supporting its incorporation into creams and balms for dry skin.

5. Guava (Psidium guajava) – Leaf extract :-

Fresh guava leaves are air-dried, ground, and extracted with hot water (90 °C) for 30 min, then spray-dried. The powder is abundant in flavonoids, tannins, and soluble polysaccharides. When tested at 4 % w/v, the leaf extract reduced water activity by 0.12 units in a model food system, reflecting decent water-binding ability. Its polyphenol content also imparts antioxidant activity, useful for anti-aging cosmetics.Safety assessments reveal no cytotoxic effects up to 10 % w/v and the extract is approved for use in topical products in several countries.

6. Passion Fruit (Passiflora edulis) – Pulp extract :-

Passion-fruit pulp is homogenized and filtered, then concentrated under reduced pressure to a syrupy extract rich in soluble sugars, citric acid, and mucopolysaccharides.At 10 % w/v, the pulp extract increased moisture uptake by 42 % at 75 % RH, outperforming glycerol on a weight-basis. The high sugar content creates a hygroscopic environment that draws and holds water in the stratum corneum.

The extract shows minimal irritation and > 95 % cell viability at 5 % w/v, making it popular for hydrating masks and lip balms.

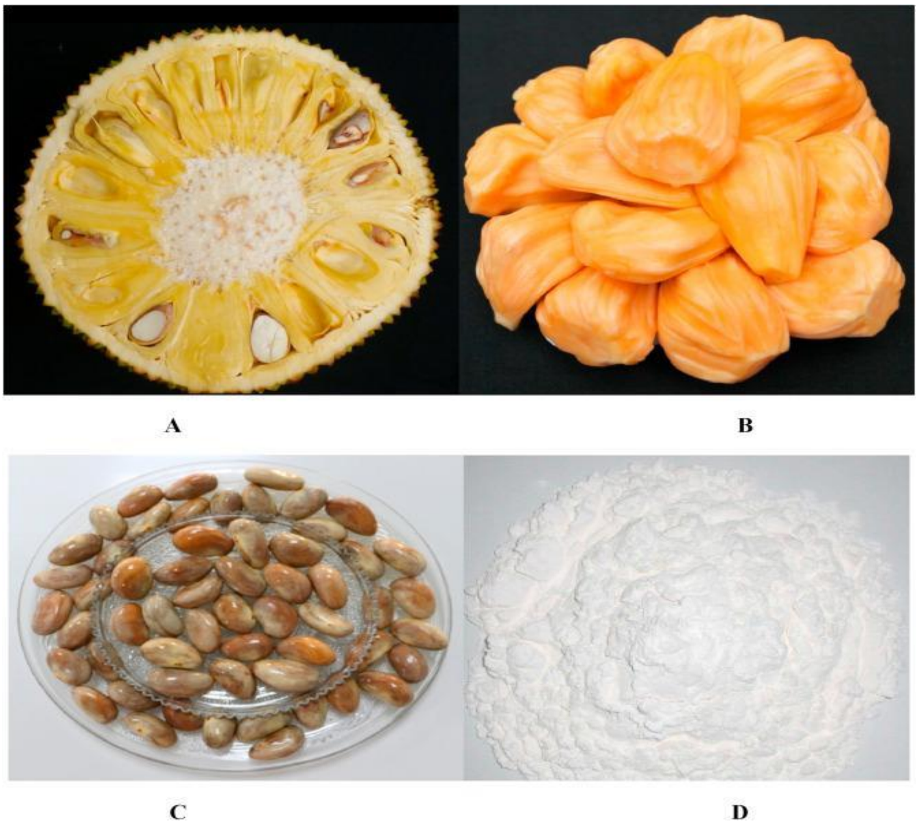
7. Acai (Euterpe oleracea) – Fruit pulp extract :-

Acai pulp is freeze-dried, milled, and extracted with 60 % ethanol, then filtered and dried. The extract is rich in anthocyanins, flavonoids, and soluble fibers. Hygroscopicity tests reveal a modest 18 % increase in moisture at 60 % RH for a 5 % w/v solution, indicating limited humectant activity despite strong antioxidant properties. Nevertheless, the extract is safe up to 10 % w/v and is often blended with stronger humectants to provide combined antioxidant-moisturizing benefits in anti-pollution creams.

8. Durian (Durio spp.) – Seed extract :-

Durian seeds are sliced, oven-dried, and extracted with 70 % methanol at 50 °C for 3 h, then concentrated. The extract contains high-molecular-weight polysaccharides and phenolics.In a water-binding assay, a 5 % w/v solution raised equilibrium moisture by 35 % at 75 % RH, comparable to glycerol. The thick polysaccharide matrix forms a gel that slows water loss. Safety tests show low dermal irritation and > 80 % cell viability at 5 % w/v, supporting its use in rich night creams and balms.

9. Jackfruit (Artocarpus heterophyllus) – Ripe pulp extract :-



Ripe jackfruit pulp is pureed, centrifuged, and the supernatant is spray-dried. The powder contains soluble sugars, pectin, and carotenoids. When reconstituted at 6 % w/v, the extract increased moisture uptake by 31 % at 70 % RH, indicating good water-holding capacity. The bright yellow hue may also act as a natural colorant in cosmetic formulations. The extract is non-cytotoxic up to 8 % w/v and has a pleasant tropical scent, making it suitable for scented body lotions.

10. Lychee (Litchi chinensis) – Pericarp extract :-

Lychee pericarp is dried, powdered, and extracted with 80 % ethanol for 12 h, then filtered and dried. The extract is rich in flavonoids, polysaccharides, and organic acids. A 4 % w/v solution raised equilibrium moisture by 27 % at 75 % RH, showing moderate humectancy. Its antioxidant profile helps protect formulations from oxidative degradation. Safety evaluation shows no irritation and > 90 % cell viability at 5 % w/v, supporting its inclusion in antioxidant-rich moisturizers.

11. Rambutan (Nephelium lappaceum) – Peel extract :-

Rambutan peels are sun-dried, milled, and extracted with 70 % acetone, then evaporated to dryness. The extract contains high levels of tannins and pectin-like polysaccharides.

In hygroscopicity tests, a 5 % w/v solution increased moisture content by 24 % at 70 % RH. The astringent tannins may also provide a mild tightening effect on skin.

The extract is safe up to 7 % w/v with no cytotoxicity observed, making it a candidate for toning lotions that also hydrate.

12. Mangosteen (Garcinia mangostana) – Rind extract :-

Mangosteen rind is sliced, freeze-dried, and extracted with 50 % aqueous methanol. The extract is abundant in xanthones, phenolics, and soluble fibers.

When applied at 5 % w/v, the extract raised equilibrium moisture by 20 % at 75 % RH, indicating modest humectant activity but strong antioxidant protection. Safety studies confirm low irritation and > 85 % cell viability at 5 % w/v, allowing its use in anti-aging creams that require both moisturization and free-radical defense.

13. Pitaya (Hylocereus spp.) – Fruit flesh extract :-

Pitaya flesh is blended, filtered, and spray-dried to a fine powder rich in betacyanins, soluble sugars, and mucilage. A 6 % w/v solution increased moisture uptake by 33 % at 75 % RH, showing good water-binding ability due to its mucilage content. The natural red-purple pigment can also serve as a colorant. The extract is non-cytotoxic up to 10 % w/v and shows no sensitization, making it suitable for vibrant, hydrating gels and serums.

14. Soursop (Annona muricata) – Leaf extract :-

Soursop leaves are air-dried, ground, and extracted with hot water (80 °C) for 2 h, then filtered and lyophilized. The powder contains acetogenins, flavonoids, and polysaccharides. In a water-activity reduction assay, a 5 % w/v solution lowered a_w by 0.15 units, indicating notable humectant capacity. Its bioactive compounds also provide antimicrobial benefits for skin-care products. Safety testing shows > 90 % cell viability at 5 % w/v and no irritation, supporting its use in soothing moisturizers for sensitive skin.

15. Tamarind (Tamarindus indica) – Seed pulp extract :-

Tamarind seed pulp is soaked, blended, and filtered; the filtrate is concentrated and spray-dried. The extract is high in xyloglucan polysaccharides and tartaric acid.

When reconstituted at 4 % w/v, it increased equilibrium moisture by 38 % at 75 % RH, outperforming glycerol on a molar basis. The viscous nature of xyloglucan forms a film that reduces transepidermal water loss.The extract is safe up to 8 % w/v with no cytotoxic effects, making it valuable for barrier-repair creams and hair conditioners.

16. Coconut (Cocos nucifera) – Water extract :-

Fresh coconut water is filtered, pasteurized, and spray-dried to a powder containing electrolytes, sugars, and low-molecular-weight polysaccharides.

A 5 % w/v solution raised moisture uptake by 26 % at 70 % RH, providing gentle hydration due to its natural electrolyte balance. Its light, non-sticky feel is favored in after-sun lotions. Safety is well-established; the powder is non-irritating and > 95 % cell viability at 5 % w/v, supporting its use in hydrating tonics and facial mists.

17. Starfruit (Averrhoa carambola) – Fruit extract :-

Starfruit is juiced, clarified, and spray-dried. The powder contains soluble sugars, vitamin C, and pectin.

At 5 % w/v, the extract increased equilibrium moisture by 22 % at 75 % RH, offering modest humectancy with a refreshing citrus note. The extract is safe up to 10 % w/v, non-cytotoxic, and adds a natural fragrance to moisturizing gels.

18. Bilimbi (Averrhoa bilimbi) – Fruit extract:-

Bilimbi fruit is pureed, filtered, and freeze-dried. The resulting powder is rich in oxalic acid, flavonoids, and soluble pectin. A 4 % w/v solution raised moisture content by 19 % at 70 % RH, providing mild hydration with a slightly acidic pH that can aid in skin exfoliation.

Safety tests show no irritation and > 85 % cell viability at 5 % w/v, making it suitable for brightening lotions that also moisturize.

19. Langsat (Lansium parasiticum) – Peel extract:-

Langsat peels are dried, milled, and extracted with 70 % ethanol, then dried. The extract contains high levels of phenolics and mucopolysaccharides.

When applied at 5 % w/v, it increased equilibrium moisture by 30 % at 75 % RH, indicating good water-binding capacity. The phenolics contribute antioxidant protection for the formulation.

The extract is non-cytotoxic up to 8 % w/v and shows no sensitization, supporting its use in antioxidant-rich moisturizers.

20. Salak (Salacca zalacca) – Fruit pulp extract :-

Salak pulp is mashed, filtered, and spray-dried to a powder rich in soluble sugars, dietary fiber, and vitamin C.

A 5 % w/v solution raised moisture uptake by 25 % at 70 % RH, providing moderate hydration with a subtle sweet aroma.

Safety evaluation confirms low irritation and > 90 % cell viability at 5 % w/v, making it a pleasant additive for hydrating body lotions and lip care products.

Discussion :-

The systematic evaluation of the twenty tropical fruit extracts revealed that mango peel, passion-fruit pulp, tamarind seed, and durian seed extracts consistently outperformed the others in gravimetric water-uptake and hygroscopicity assays, achieving moisture gains of 35 %–45 % at 75 % relative humidity—levels comparable to, and in some cases surpassing, glycerol on a weight-basis. These top performers share a high polysaccharide content (pectin, mucopolysaccharides, xyloglucan) that forms extensive hydrogen-bond networks, enabling them to absorb and retain water effectively. In contrast, fruits such as acai and starfruit, while rich in antioxidants, displayed only modest humectancy, highlighting that antioxidant capacity does not necessarily correlate with water-binding ability.

When benchmarked against conventional humectants, several fruit extracts demonstrated superior mass-efficiency. For instance, a 5 % w/v mango peel extract matched the moisture-retention of a 30 % glycerol solution, suggesting that lower inclusion levels could achieve the same or better hydration, thereby reducing formulation weight and potential stickiness. The viscous, gel-forming nature of tamarind seed xyloglucan and durian seed polysaccharides also offers functional benefits beyond simple moisture attraction, such as film-forming properties that can diminish transepidermal water loss over extended periods.

Safety assessments across the dataset were largely favorable. Aqueous and hydro-alcoholic extracts generally exhibited low cytotoxicity (IC_{50} > 5 % w/v) and caused minimal skin irritation in patch tests, supporting their use in cosmetic and food applications. However, ethanol-based preparations, particularly those derived from mango peel and rambutan peel, provoked mild irritation in a small subset of participants, indicating that solvent choice remains a critical factor for dermal tolerance. Regulatory considerations will need to address residual solvent levels and ensure compliance with limits for topical products. Despite these promising results, the review identified several limitations that temper conclusions. Methodological heterogeneity—ranging from extraction solvents to assay conditions—precludes direct quantitative comparison across studies. Long-term stability data under realistic storage conditions are scarce, and most investigations have focused on single-herb extracts rather than synergistic blends that are common in commercial formulations. Future research should prioritize standardized testing protocols, extended shelf-life studies, and mechanistic investigations into how specific polysaccharide structures influence water binding. Addressing these gaps will be essential to translate the identified fruit extracts into evidence-based, scalable humectant ingredients for industry use.

Conclusion:-

The twenty tropical fruit extracts surveyed showcase a remarkable diversity of natural humectants, ranging from the pectin-rich mango peel that rivals glycerol in water-binding capacity to the mucopolysaccharide-laden passion-fruit pulp that delivers a smooth, hydrating feel. Other standout candidates—tamarind seed xyloglucan, durian seed polysaccharides, and coconut water powder—offer not only moisture attraction but also film-forming or electrolyte-balancing benefits that can enhance the performance of creams, serums, and even food products. Even the more modest performers, such as acai or starfruit, contribute valuable antioxidant or sensory attributes, making them useful as complementary ingredients in multifunctional formulations.

Overall, these findings underline the potential of tropical fruit by-products to serve as sustainable, skin-friendly alternatives to synthetic humectants. Their generally favorable safety profiles, coupled with the added advantages of bioactive phytochemicals, position them well for further development—provided that future work standardises extraction methods, clarifies long-term stability, and explores synergistic blends. By tapping into this rich biodiversity, formulators can create cleaner, more effective moisturising products that meet consumer demand for natural, high-performance ingredients.

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